BCA611 Video Oyunları için 3B Grafik

Ders 9
Phong Lighting Model

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https://zumrakavafoglu.github.io/

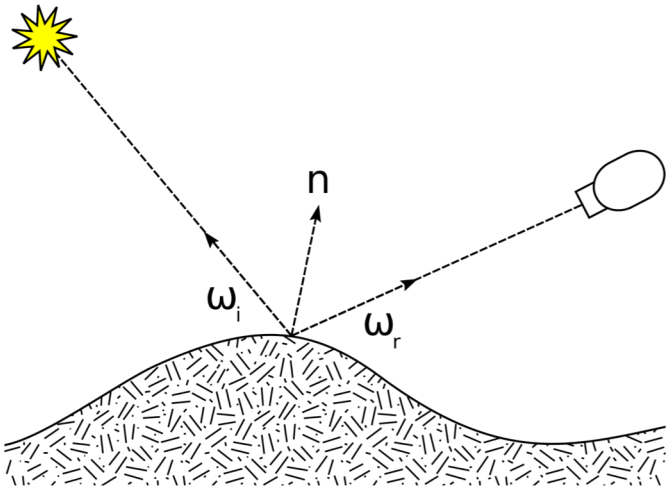
Ders notlarının bu kısmı 3D Computer Graphics for Game Programming(J. Han) kitabının slaytlarından derlenmiştir.

What is Illumination?

- Illumination or lighting refers to the techniques handling the interaction between light sources and objects.
- The lighting models are divided into two categories.
  - Local illumination considers only direct lighting in the sense that the illumination of a surface depends solely on the properties of the light sources and the surface materials. This has been dominant in real-time graphics.
  - In the real world, however, every surface receives light indirectly. (Even though a light source is invisible from a particular point of the scene, light can still be transferred to the point through reflections or refractions from other surfaces of the scene.) For indirect lighting, the global illumination (GI) model considers the scene objects as potential lighting sources.
- Problems of interactive GI
  - The cost is often too high to permit interactivity.
  - The rasterization-based architecture of GPU is more suitable for local illumination.
- Current status of GI
  - Approximate GI instead of pursuing precise GI.
  - Pre-compute GI, store the result in a texture, and use it at run time.

BRDF(Bidirectional Reflectance Distribution Function)

- For rendering a surface illuminated by a light source, we need to represent the irr adiance measured at the surface and the outgoing radiance reaching the camera.
- The relationship between them is described by BRDF (bidirectional reflectance di stribution function)
- In a more simplified manner, The bidirectional reflectance distribution function (BRDF) is a function of four real variables that defines how light is reflected at an opaque surface.
- A simplified BRDF was proposed by Phong



Phong Lighting Model

- Local illumination technique
- Before 2001the fixed-function pipelines were slight variations of the Phong mo del.
- The local illumination model is physically incorrect, and so is the Phong model.
- Therefore, the rendering result is not photorealistic and can be easily recognize d as computer-generated.
- The state of the art in real-time lighting has been gradually moving away from t he classic implementation of the Phong lighting model.
- Programmability in GPU enables us to extend the local illumination model and implement a variety of more physically correct algorithms.
- Nonetheless, the Phong model is still widely adopted in commercial games and lays foundations of various advanced lighting techniques.

Phong Lighting Model

- In the Phong model, the perceived color of a surface point is defined by four term s named diffuse, specular, ambient, and emissive.
- **The diffuse and specular terms** deal with the light ray directly coming from the light source to the surface point to be lit
- **Ambient term** accounts for indirect lighting.
- **The emissive term** applies for the object emitting light itself.

Phong Lighting Model

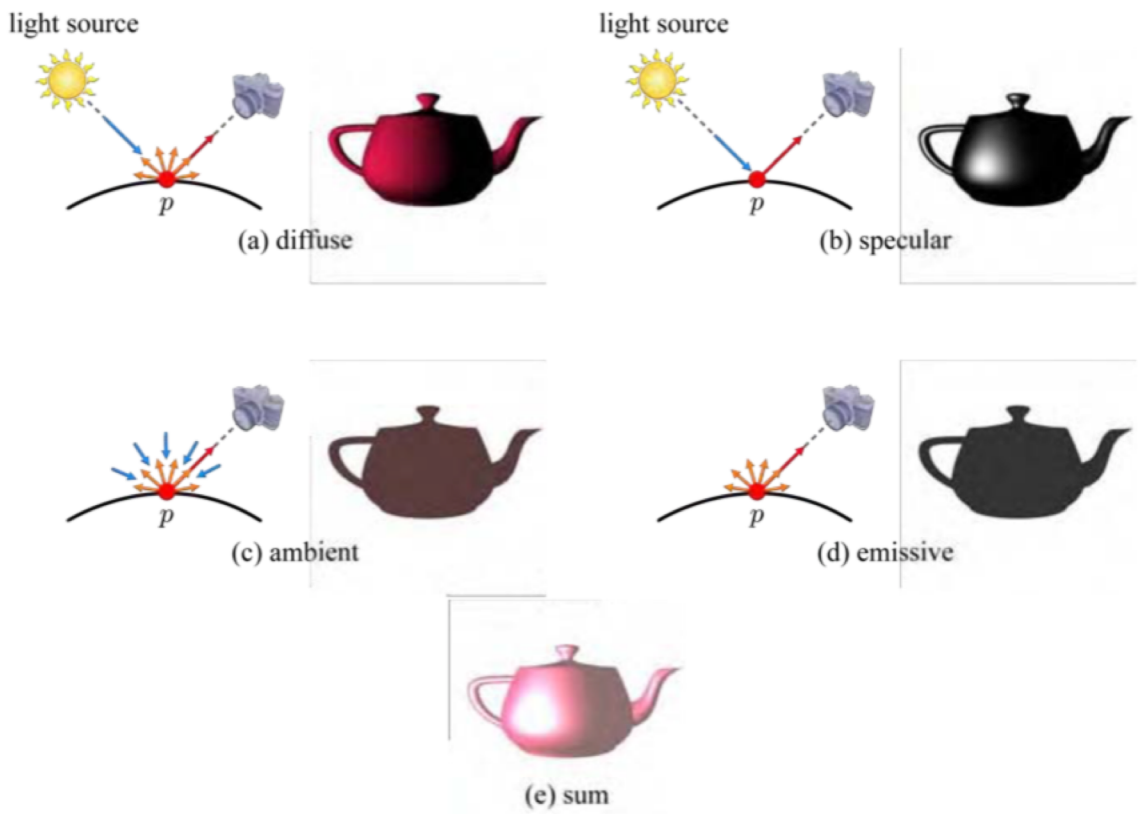
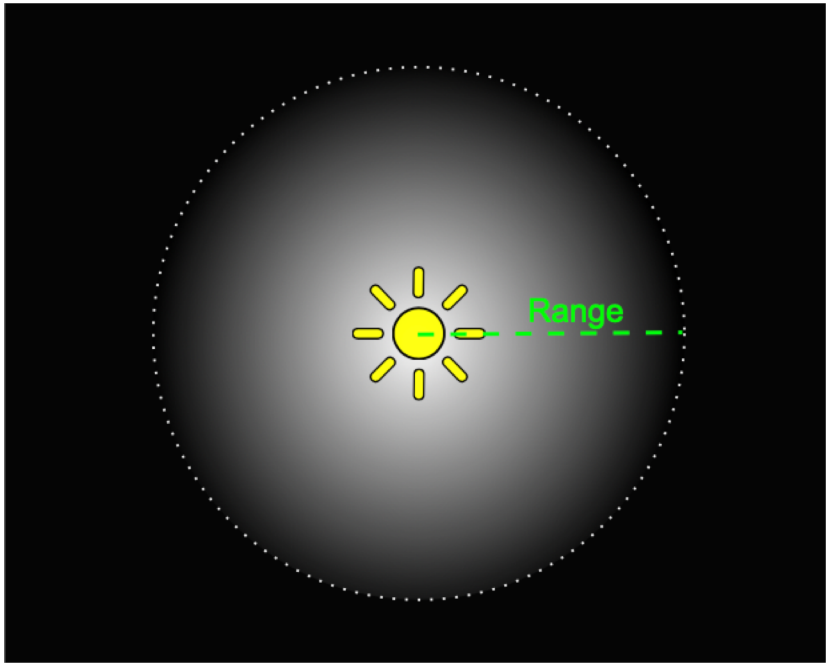


Fig. 5.1: Light incident on p is illustrated in blue, and reflected light is in orange color. Outgoing radiance reaching the camera is illustrated in red.

Light source types : Point Light

- **Point light :**
  - Located at a point in space
  - Sends light out in all directions equally
  - Direction of light back to the center of the light object
  - The intensity diminishes with distance from the light, reaching zero at a specified range.
  - Inverse square law: Light intensity is inversely proportional to the square of t he distance from the source.

Light source types : Point Light

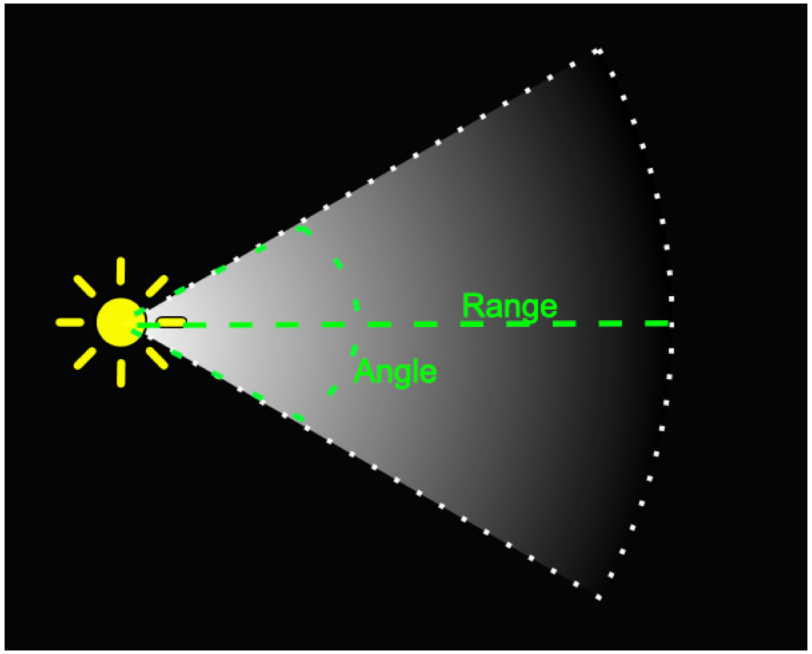


https://docs.unity3d.com/Manual/Lighting.html

Light source types : Spot Light

- **Spot lights :**
  - has a specified location and range over which the light falls off
  - the spot light is constrained to an angle, resulting in a cone-shaped region of i llumination.
  - Direction of light back to the center of the light object back to the center of th e light object.
  - Light also diminishes at the edges of the spotlight's cone
  - Penumbra: Widening the angle increases the width of the cone and with it increases the size of this fade
  - Spot lights are generally used for artificial light sources such as flashlights, car headlights and searchlights.
  - With the direction controlled from a script or animation, a moving spot light will illuminate just a small area of the scene and create dramatic lighting effects.

Light source types : Spot Light



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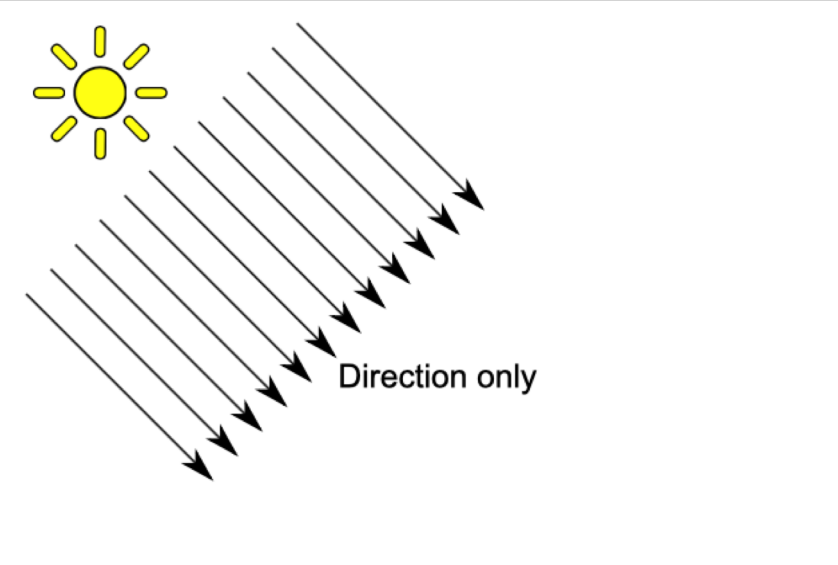
Light source types : Directional Light

- **Directional lights :**
  - Directional lights can be thought of as distant light sources which exist infinit ely far away.
  - A directional light does not have any identifiable source position and so the li ght object can be placed anywhere in the scene.
  - All objects in the scene are illuminated as if the light is always from the same direction
  - The distance of the light from the target object is not defined and so the light does not diminish
  - Directional lights represent large, distant sources that come from a position outside the range of the game world.
  - In a realistic scene, they can be used to simulate the sun or moon

Light source types : Directional Light



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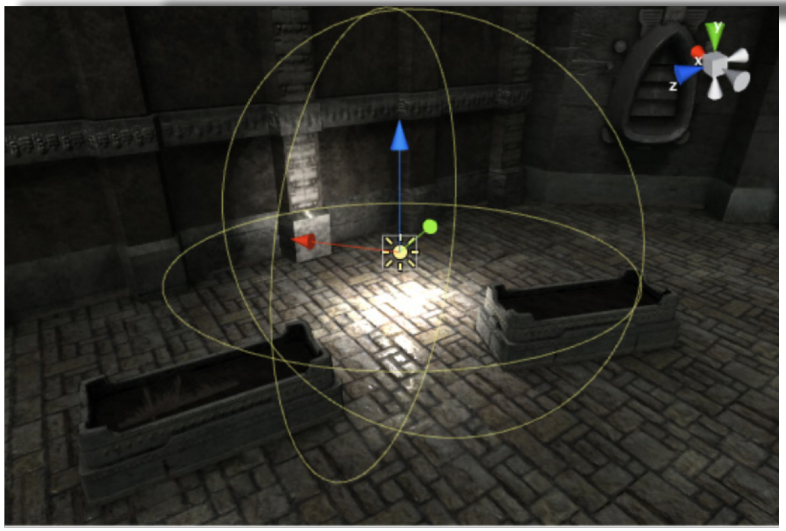
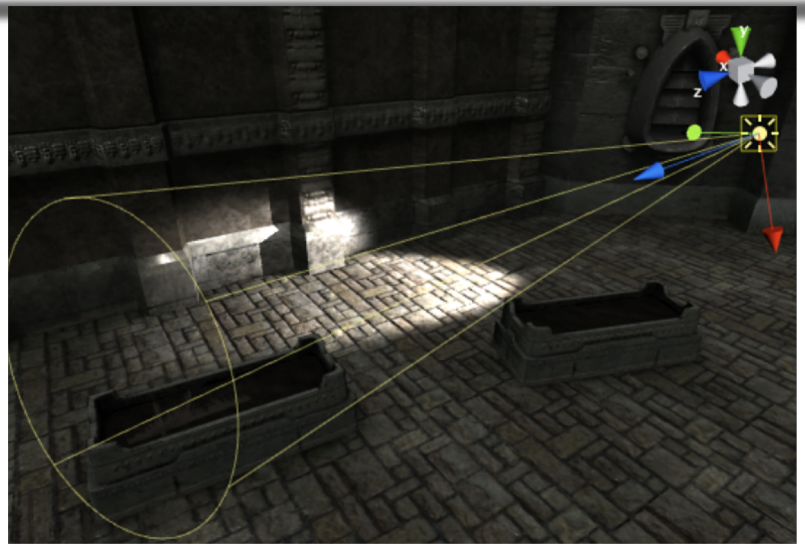
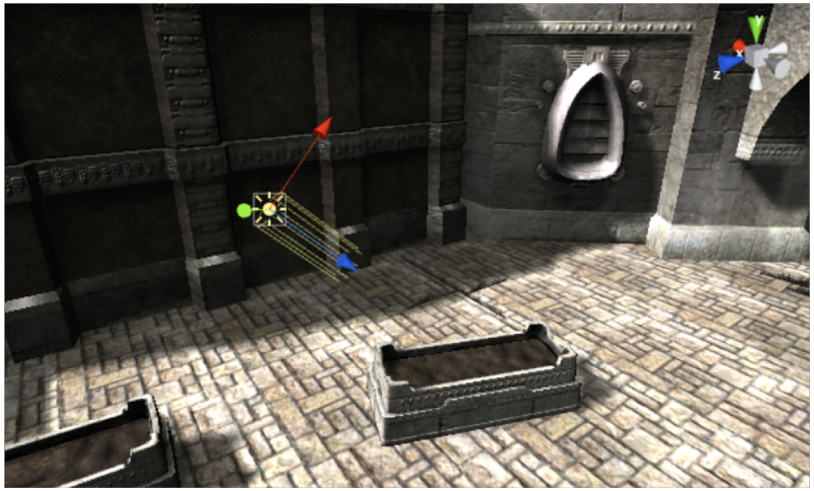
Light source types



Point light



Spot light



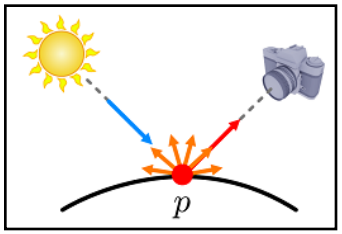
Directional light

https://docs.unity3d.com/Manual/Lighting.html

Phong Lighting Model for Directional Light Sources

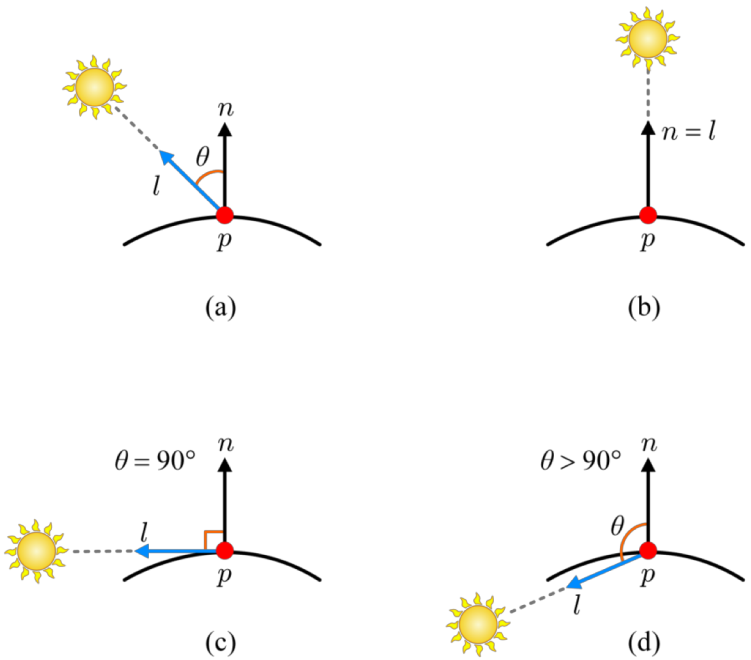
Phong Lighting Model - Diffuse Term

- The diffuse term is based on Lambert's law. Reflections from ideally diffuse surfaces (Lambertian surfaces) are scattered with equal intensity in all directions.
- So, the amount of perceived reflection is independent of the view direction, and is just proportional to the amount of incoming light.



Phong Lighting Model - Diffuse Term

- The incident angle θ of light at p is between l and the surface normal n. If θ bec omes smaller, p receives more light.
- Assuming l and n are normalized, the dot product of n and l is used to measure t he amount of incident light.
- Compare the perceived amount of lights below with different incident angles



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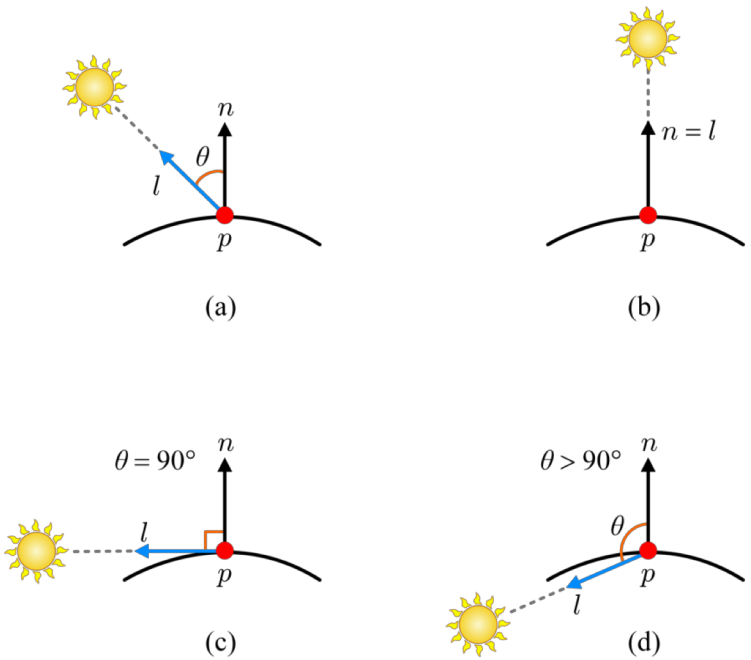


$$max(n \cdot l, 0)$$

Determines the amount of incident light

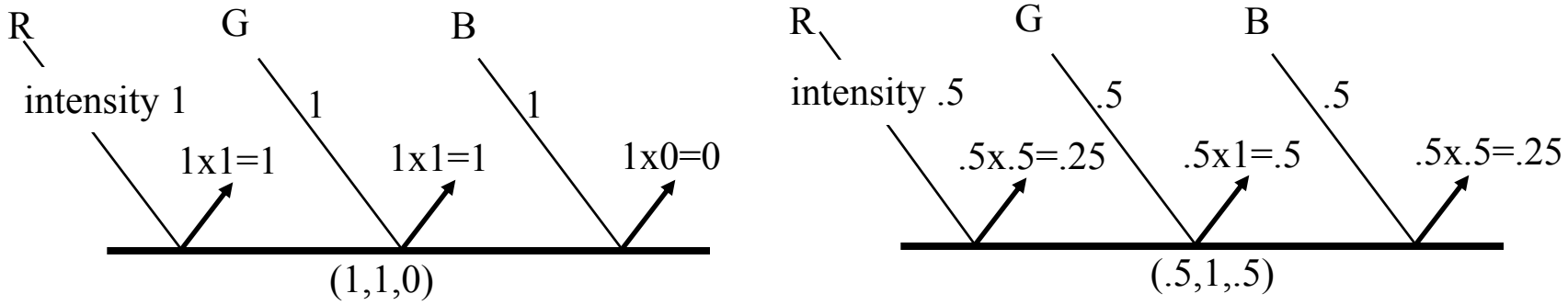
Perceived color of the surface point

- Note that max(n · l, 0) determines only the 'amount' of incident light.
- The perceived color of the surface point p is defined as follows, where
  - s_d is the RGB color of the light
  - m_d is the diffuse reflectance of the object material
  - $\otimes$ represents the component-wise multiplication.

$$s_d \otimes m_d$$

Perceived color of the surface point

- Suppose a white light (1,1,1). If an object lit by the light appears yellow, it means that the object reflects R and G and absorbs B.
- We can easily implement this kind of filtering through material parameter, i.e., if it is (1,1,0), then (1,1,1)⊗(1,1,0)=(1,1,0) where ⊗ is component-wise multiplication.

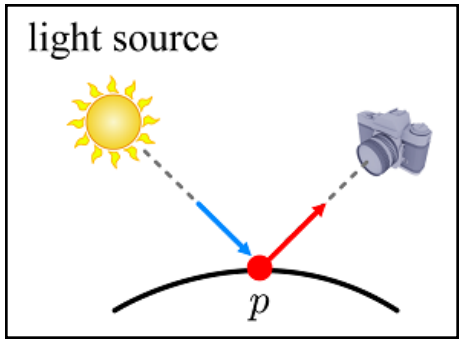


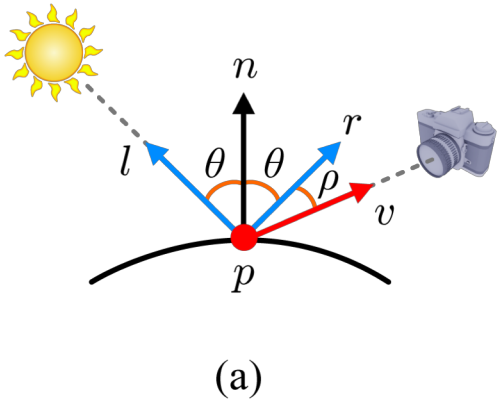
$$s_d \otimes m_d$$

- The diffuse term: $max(n \cdot l, 0) s_d \otimes m_d$

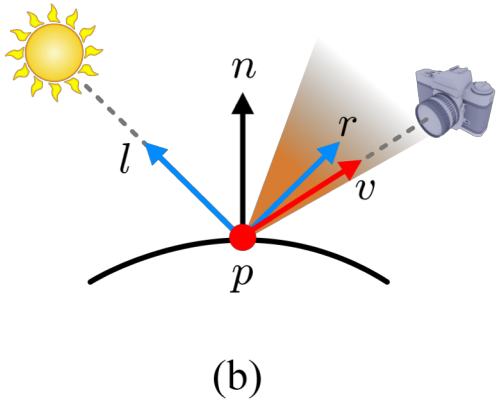
Phong Lighting Model - Specular Term

- The specular term is used to make a surface look shiny via *highlights*, and it requires *view vector* (v) and *reflection vector* (r) in addition to *light vector* (l).





(a)



(b)

Phong Lighting Model - Specular Term

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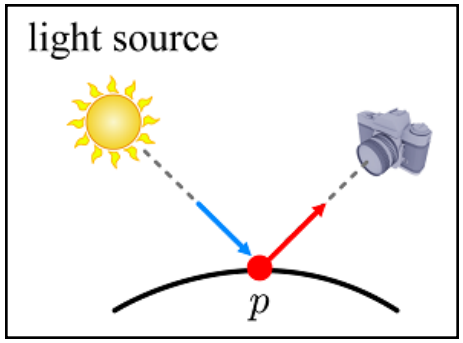
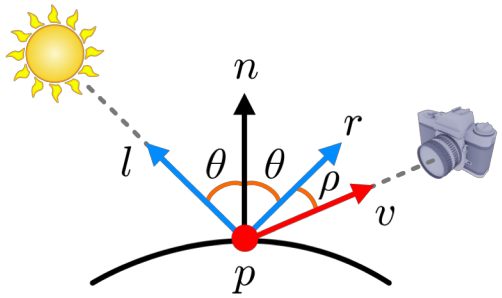
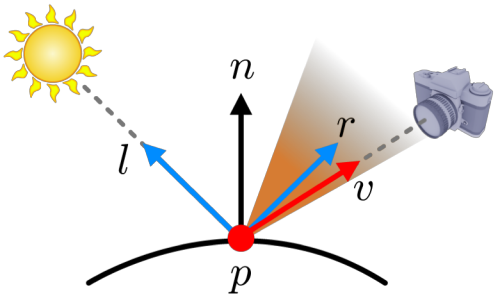


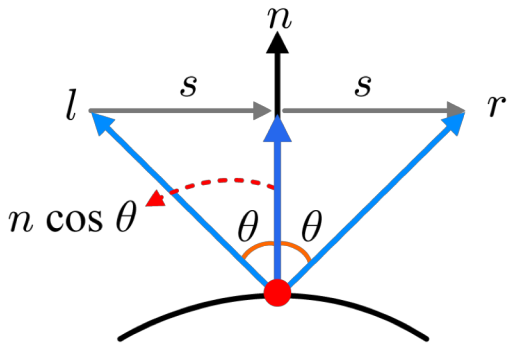


(a)



(b)

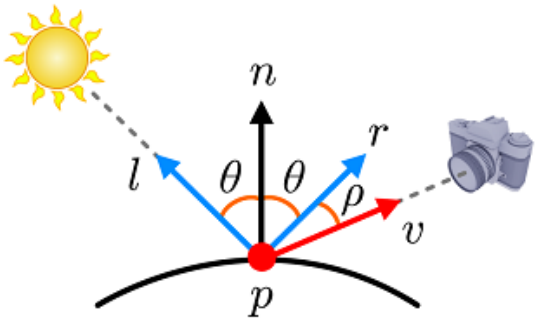
- Computing the reflection vector

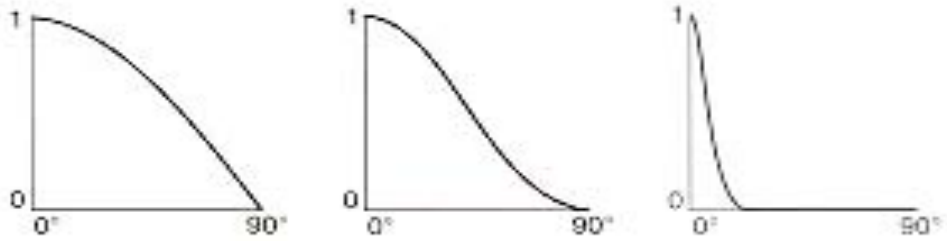


$$s = n\cos\theta - l$$
$$s = r - n\cos\theta$$
$$r = 2n\cos\theta - l$$
$$= 2n\,(n\cdot l) - l$$

Phong Lighting Model - Specular Term (cont'd)

- Whereas the diffuse term is view-independent, the specular term is highly view-dependent.
  - For a perfectly shiny surface, the highlight at p is visible only when ρ equals 0.
  - For a surface that is not perfectly shiny, the maximum highlight occurs when ρ equals 0, but falls off sharply as ρ increases.
  - The rapid fall-off of highlights is often approximated by $(r \cdot v)^{sh}$, where sh denotes shininess. (r.v = cos(ρ))



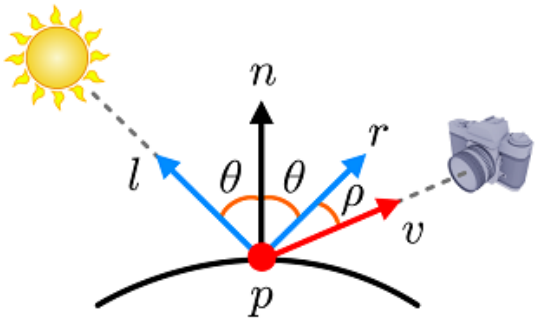


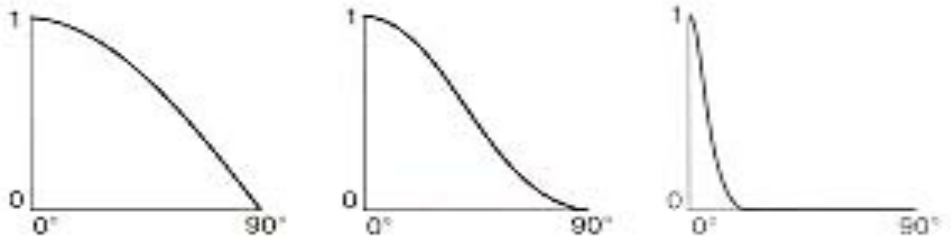
$cos\rho$ $cos^2\rho$ $cos^{64}\rho$

$$(r \cdot v)^{sh}$$

Phong Lighting Model - Specular Term (cont'd)

- When r = v, $(r \cdot v)^{sh} = 1$, regardless of the value sh, and the maximum highlight is visible to the camera.
- When r ≠ v, the highlight is less likely to be visible as sh increases.

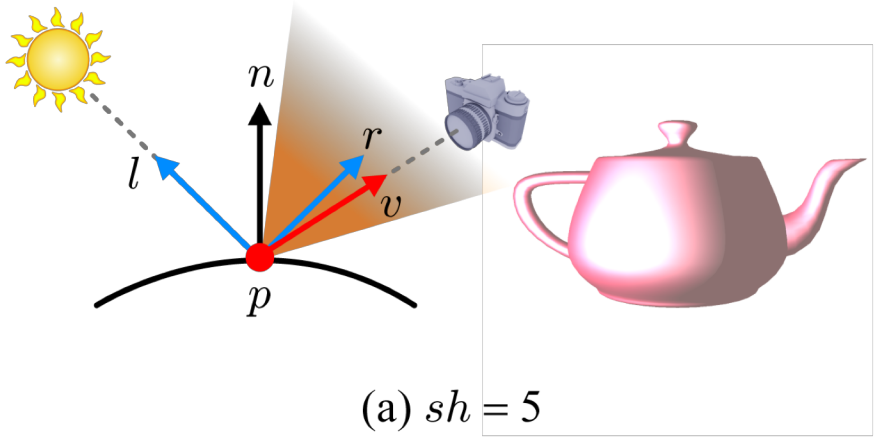




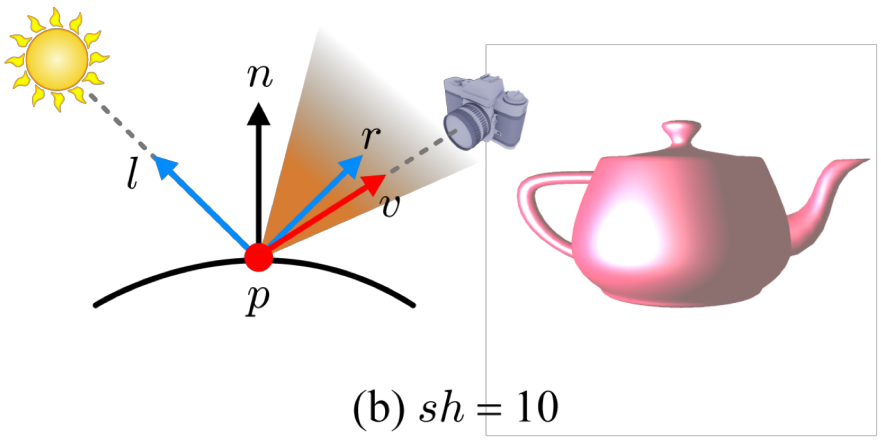
$cos\rho$ $cos^2\rho$ $cos^{64}\rho$

$(r \cdot v)^{sh}$

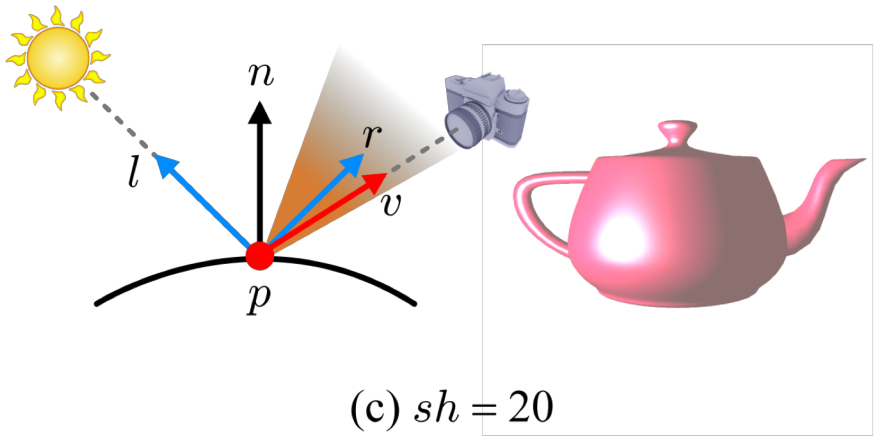
Phong Lighting Model - Specular Term (cont'd)



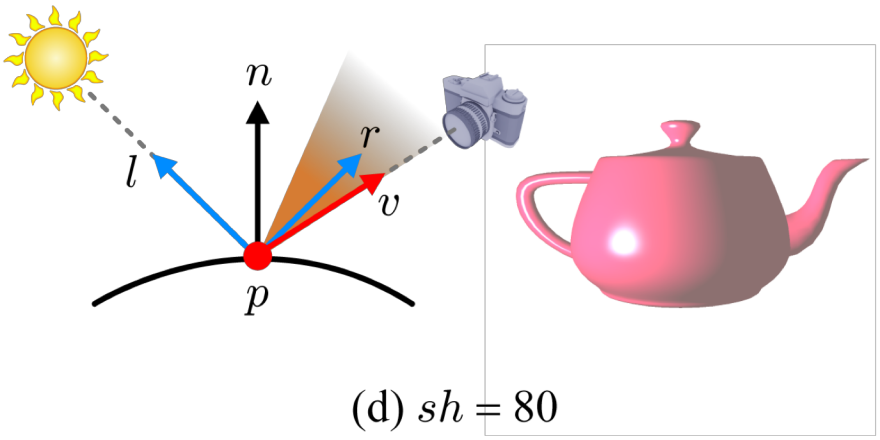
(a) $sh = 5$



(b) $sh = 10$



(c) $sh = 20$



(d) $sh = 80$

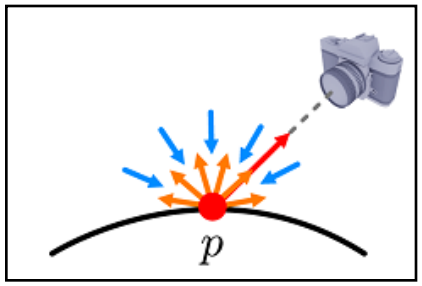
Phong Lighting Model - Specular Term (cont'd)

- The specular term: $(max(r \cdot v, 0))^{sh} s_s \otimes m_s$

- Unlike m_d, m_s is usually a gray-scale value rather than an RGB color. It enables the highlight on the surface to end up being the color of the light source.

Phong Lighting Model – Ambient Term

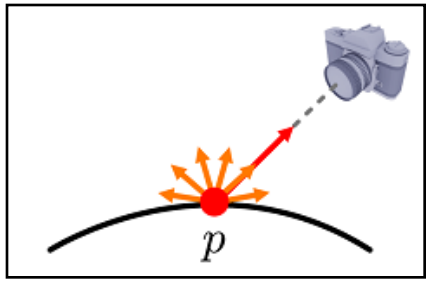
- The ambient light describes the light reflected from the various objects in the scene, i.e., it accounts for *indirect lighting*.
- As the ambient light has bounced around so much in the scene, it arrives at a surface point from all directions, and reflections from the surface point are also scattered with equal intensity in all directions.
- The amount of ambient light incident on a surface point is independent of the surface orientation, and the amount of perceived reflection is independent of the view direction.
- The rendering result simply looks like a 2D object because there is no difference in shade across the teapot's surface.



$s_a \otimes m_a$

Phong Lighting Model – Ambient and Emissive Terms

- The last term of the Phong model is the emissive term m_e that describes the amount of light emitted by a surface itself.



Phong Lighting Model

- The Phong model sums the four terms!!

$$max(n \cdot l, 0)s_d \otimes m_d + (max(r \cdot v, 0))^{sh} s_s \otimes m_s + s_a \otimes m_a + m_e$$